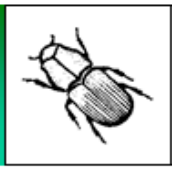
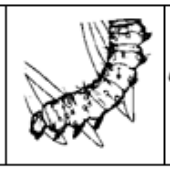
Forest Health Protection

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Assessment of Suitable Douglas-fir Beetle Habitat across the Northern Region: Special Emphasis on 2017 Wildfire Incidents

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Introduction

Fire-injured trees resulting from wildfires can provide suitable habitat for bark beetles, wood boring beetles, *Ips* spp., and other secondary beetles (Coleoptera: Buprestidae, Cerambycidae, Curculionidae) to colonize and reproduce within (Appendix A; Egan 2014). This habitat can facilitate insect population amplifications within fire perimeters that can influence post-fire tree mortality (Appendix A). Virtually all conifers have a guild of insect species that can increase populations in fire-injured host material.

While fire-injured trees promote insect population amplifications, it is rare for insects to spill-over into adjacent healthy trees (Davis et al. 2012; Powell et al. 2012). In most cases, fire-injured trees act as a temporary sink for beetles and do not substantially increase risk to stands outside the fire perimeter. Occasionally, wildfire events do occur in conjunction with ambient conditions conducive to beetle-related tree mortality in adjacent, unburned forests. Generally, outbreaks require susceptible stand conditions that provide suitable reproductive habitat, tree vulnerability to beetle-attack within that habitat, outperformance of erupting beetle species in relation to other species competing for scarce resources, and a release of erupting species from regulatory complexes that influence population dynamics and insect mortality (i.e. predators, parasitoids, diseases, cold weather, etc.) (Carroll et al. 2006; Raffa et al. 2008).

Resource managers have been especially concerned about the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins, DFB). DFB is an aggressive bark beetle species that can erupt to cause severe tree mortality when a catalyst (typically blowdown or a wildfire event) occurs in conjunction with ambient conditions favorable to DFB population releases near suitable host trees that are vulnerable to beetle-attack. Suitable Douglas-fir stands contain older trees ($\geq$120 years in age) that are large-diameter ($\geq$14" DBH) and located in dense stands (especially those $\geq$250 feet^2 per acre of basal area) composed primarily of Douglas-fir (Weatherby and Thier 1993; Randall et al. 2011). This suitable habitat has increased risk of attack, and is considered vulnerable, when trees have reduced tree vigor due physiological stressors.

Such stressors can be acute, short-term factors (e.g. protracted or severe drought, defoliation events, low-severity fire-injury) and/or chronic, long-term stressors (root disease infection, vegetative competition, and genetic predisposition).

Multiple stochastic factors across various ecological scales need to align for DFB eruptions to cause severe and widespread tree mortality near 2017 wildfire events. Thus, it is not possible to predict the likelihood of an outbreak occurring. However, it is possible to assess where 1) the abundance and location of suitable habitat that has the 'potential' to support a DFB outbreak event and 2) identify where potential habitat is likely to have elevated 'probability' of DFB-attack due to fire damage.

Objectives for this analysis were to use best-available vegetation and burn severity data to 1) estimate the distribution of suitable DFB habitat across the Northern Region (i.e. potential habitat); 2) assess suitable habitat abundance within and adjacent to 2017 wildfire incidents; 3) identify where suitable DFB habitat intersects with fire damage (i.e. probable habitat); and 4) identify wildfire incidents where concern for post-fire DFB activity is greatest. Data were not available for all 2017 wildfire incidents at the time this report was written. However, geospatial layers from these methods were updated for all 2017 wildfire incidents after this report was published.

Best-available data was obtained from combining coarse datasets to assess tree and stand-level criteria known to be conducive to DFB-attack with surrogate variables. Therefore, results from this work should be combined with local expertise and/or field surveys to ensure vegetative and fire-injury conditions estimated with coarse data are reasonable.

Information in this report can directly support resource manager efforts to assist in identifying 1) locations within 2017 wildfire events where probability of DFB-attack is increased due to partial burn severity in suitable DFB habitat; 2) assess whether sufficient suitable habitat exists to support a severe and widespread DFB outbreak near wildfire incidents or for other project areas; and 3) where subsequent surveys may be needed to monitor DFB activity for purposes beyond initial wildfire salvage efforts.

Methods

Detailed description of geospatial processing methods, data, and attributes used for analysis are provided in Appendix B.

Geospatial data from Northern Region Existing Vegetation Map (R1 VMap) products, which are derived from National Agriculture Imagery Program (NAIP) data, were obtained to estimate suitable DFB habitat within and adjacent to 2017 wildfire incidents (Brown and Barber 2011; Ahl and Brown 2017; Brown et al. 2017). This effort was expanded region-wide to provide coarse-level DFB habitat suitability estimates for project-use outside the scope of the 2017 fire-salvage efforts.

DFB susceptibility was assessed by matching criteria from Randall et al. (2011) to closest R1 VMap attributes in conjunction with Forest Health Protection entomologist expert opinion.

Detailed criteria (see Appendix B) were used to estimate low, moderate, and high levels of susceptibility to represent conservative (high-susceptibility only) and liberal (moderate [mod] +high susceptibility) estimates. This approach provided a range of estimates as 1) R1 VMap data used to estimate DFB susceptibility had accuracy levels (range 52-77%) that varied by attribute and Forest product (Brown 2011; Ahl and Brown 2017; Brown et al. 2017) and 2) R1 VMap attributes used were often best-available surrogates for stand-level DFB susceptibility rating criteria (Randall et al. 2011; Weatherby and Thier 1980s). As newer R1 VMap products become available, geospatial layers representing DFB susceptibility will be updated.

Susceptibility estimations were validated with best-available coarse-scale data by comparing percent of Forest Inventory and Analysis (FIA) subplot data, with mod+high susceptibility ratings assigned from Randall et al. (2011), to the percent of total fire incident area estimated to contain mod+high susceptibility from R1 VMap estimates (Appendix B). This occurred across six wildfire incidents that spanned 310,627 acres and contained 233 FIA subplots.

Following susceptibility stratification, R1 VMap polygons estimated to have suitable DFB habitat were intersected with the Rapid Assessment of Vegetation Condition following Wildfire (RAVG) and Soil Burn Severity (SBS) hybrid layer (RAVG+SBS) described in the NRGG (2017) document assessing post-fire, Canada lynx (*Lynx canadensis*) habitat. This hybrid fire severity analysis combined information from remote sensing (Landsat TM) and Burned Area Emergency Rehabilitation team assessments to quantify the immediate "effects of the fire on stand vegetation" (NRGG 2017). Intersections indicated where DFB susceptible habitat was anticipated to have 1) minimal burn severity and no fire injury; 2) two levels of moderate burn severity and increased probability of DFB-attack; and 3) severe burn severity that directly killed vegetation and would not be conducive to DFB-attack. These designations were based on parameters from the Hood et al. (2007) DFB-attack model that indicates probability of DFB-attack is heightened in Douglas-fir with moderate levels of fire-injury.

Subsequently, absolute and relative totals representing conservative and liberal range of suitable or 'potential' DFB habitat within wildfire incidents, excluding polygons with severe burn severity where vegetation is estimated to be directly killed by wildfire, were totaled along with suitable habitat + partial fire-injury totals representing 'probable' DFB habitat. Fire perimeters were then buffered by respective 2 and 5-mile buffers for additional suitable DFB habitat calculations.

Results

Across the Northern Region, 7.8 million acres were identified with Douglas-fir as the dominant tree species (Map 1). Of this area, low DFB susceptibility was estimated across 1.9 million acres (24% of total area with Douglas-fir species dominance), moderate susceptibility was estimated across 3.4 million acres (44%), and high susceptibility was estimated across 2.5 million acres (32%). In total, 75% of all Douglas-fir dominated areas identified with R1 VMap products were estimated to have moderate or high susceptibility to DFB-attack.

Within 2017 wildfire incidents, each incident had varied levels of potential and probable DFB habitat. Absolute and relative area totals from this analysis are presented for Northern Region 2017 wildfire incidents within Tables 1-3.

Further area summations are detailed for select 2017 wildfire incidents within Tables 4a-4d which stratify by 1) incident extent (greater or less than 15,000 acres); 2) DFB habitat suitability and 3) RAVG+SBS burn severity classes. Representative maps showcase spatial information within these stratifications for 2017 wildfire incidents (Maps 2-7).

A coarse-level validation suggested DFB suitable habitat estimated using these methods and R1 VMap product base-data are reasonable for resource management use. Validation compared R1 VMap mod+high DFB susceptible habitat estimates with field-sampled FIA subplot data. FIA subplots had 24% of all plots within wildfire incidents rated at a moderate or high susceptibility to DFB-attack while R1 VMap assessment from this report estimated a similar 19% of the total area from the same incidents had these susceptibility classes.

Geospatial data from this analysis can be obtained from these data repository locations:

- For data related to wildfire incident salvage efforts:
  T:\FS\NFS\R01\Project\PostFire2017\GIS\DFB
- For data related to DFB suitable habitat assessment across the Northern Region:
  T:\FS\Reference\GIS\r01\Data\FHP\VMap_Hazard_DFB (layer file and documentation)
- T:\FS\Reference\GeoTool\agency\DatabaseConnection\r01_default_as_myself.sde\S_R01.FHP (GIS data)

Conclusion

Majority of Douglas-fir dominated stands across the Northern Region are estimated to be moderate or highly susceptible to DFB-attack based on R1 VMap product data.

Wildfire incidents had varied combinations of suitable DFB habitat within and adjacent to incidents as well as moderate burn severity enhancing Douglas-fir vulnerability to beetle-attack within fire perimeters. Abundance of these host conditions, along with local knowledge of ambient conditions needed to support DFB eruptions, provide critical information needed to gauge the potential for an undesirable DFB outbreak within and near 2017 wildfire incidents.

The incidents with greatest potential for DFB outbreaks identified in this assessment included: the Goat Creek, Rice Ridge, Cub Creek, Sheep Gap, Little Hogback, Moose Peak, and West Fork wildfire incidents.

Management activities within these fires, as well as other incidents with potential and probable DFB habitat, should consider monitoring and/or mitigating potential impacts of DFB activity as appropriate based on local resource objectives and tolerances for DFB-caused tree mortality.

Further information on DFB management can be found in Forest Health Protection & State Forestry Organization's management guide, Kegley (2011), at:

Douglas-fir Beetle Management
https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5187396.pdf

Works cited

Ahl, R., Brown, S. 2017. **The Bitterroot and Lolo National Forests Region 1 Existing Vegetation Database (VMap) revision of 2016.** NRGG_PR_BITLO_VMAP2016. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Geospatial Group. 18 p.

Brown, S., 2011. **Beaverhead-Deerlodge National Forest VMap Accuracy Assessment; Version 11**. R1-11-03. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Engineering. 10 p.

Brown, S., Barber, J. 2011. **The Beaverhead-Deerlodge Existing Vegetation Database (VMap) Version 11**. R1-11-01. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Engineering. 5 p.

Brown, S., Ahl, R., Kellner, F. 2017. **The Idaho Panhandle and Kootenai National Forests Region 1 Existing Vegetation Database (VMap) revision of 2017**. NRGG_PR_IPKNF_VMAP2017. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Geospatial Group. 14 p.

Carroll, A., Aukema, B., Raffa, K., Linton, D., Smith, G., Lindgren, B. 2006. **Mountain Pine Beetle Outbreak Development: The Endemic–Incipient Transition.** MPBI #1.03. Natural Resources Canada, Canadian Forest Service, Victoria, British Columbia, Canada. 22p.

Davis, R., Hood, S., Bentz, B. 2012. **Fire-injured ponderosa pine provide a pulsed resource for bark beetles**. Canadian Journal of Forest Research 42, 2022-2036.

Egan, J. 2014. **Assessment of Insect Activity and Projects Proposed for FY15 FHP Funding on the West Zone of the Gallatin National Forest**. MFO-TR-14-33. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Forest Health Protection. 11 p.

[Note: See pages 7-10 for documentation of twig beetle activity in fire-injured whitebark pines following the Millie Fire of 2012]

Hood, S., Bentz, B., Gibson, K., Ryan, K., DeNitto, G. 2007. **Assessing post-fire Douglas-fir mortality and Douglas-fir beetle attacks in the northern Rocky Mountains**. RMRS-GTR-199. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 31 p.

Kegley, S. 2011. **Management guide for Douglas-fir beetle**. 10 p. In: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation.

NRGG [Natural Resources Geospatial Group]. 2017. **Analyzing Post-Fire Habitat Conditions for Canada Lynx**. Project Report: NRGG_TG_IMT_LYNX_12_19_2017. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Engineering. 11 p.

Powell, E., Townsend, P., Raffa, K. 2012. **Wildfire provides refuge from local extinction but is an unlikely driver of outbreaks by mountain pine beetle**. Ecological Monographs 82, 69-84.

Raffa, K., Aukema, B., Bentz, B., Carroll, A., Hicke, J., Turner, M., Romme, W., 2008. **Cross-scale drivers of natural disturbances prone to anthropogenic amplification: the dynamics of bark beetle eruptions.** Bioscience 58, 501–517.

Randall, C., Steed, B., and Bush, R. 2011. **Revised R1 Forest Insect Hazard Rating System User Guide for use with Inventory Data Stored in FSVeg and/or Analyzed with the Forest Vegetation Simulator**. FHP Report R1-11-06. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Forest Health Protection. 27p.

Weatherby, J., Thier, R. 1993. **A preliminary validation of a Douglas-fir beetle hazard rating system. Mountain Home Ranger District, Boise National Forest, 1992**. R4-93-05. Boise, ID: U.S. Department of Agriculture, Forest Service, Northern Region, Forest Health Protection. 7 p.

Citation for this report

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Table 1a. Douglas-fir Beetle Suitable Habitat R1 VMap Evaluation within 2017 Wildfires

n **= 23 of 46 total incidents**

Incident	Fire Area (acres)	Conservative Area Estimates[1][2] — DFB Habitat: Potential[3] Highly Susceptible Acres	Conservative Area Estimates[1][2] — DFB Habitat: Probable[4] Highly Susceptible w/ Fire-Injury	Liberal Area Estimates[1][2] — DFB Habitat: Potential[3] Mod+Highly Susceptible Acres	Liberal Area Estimates[1][2] — DFB Habitat: Probable[4] Mod+High Susceptible w/ Fire-Injury	Conservative-Liberal[1][2] Relative Range — DFB Habitat: Potential[3] Conservative - Liberal Range (percent incident area)	Conservative-Liberal[1][2] Relative Range — DFB Habitat: Probable[4] Conservative - Liberal Range (percent incident area)
Alice Creek	29,271	2,112	474	4,722	1,153	7-16%	2-4%
Andys Hump	1,729	1	0	5	1	0-0%	0-0%
Ballinger	2,277	6	2	11	2	0-0%	0-0%
Barren Ridge	1,996	12	0	19	0	0-1%	0-0%
Blacktail Fire	5,355	202	12	343	15	4-6%	0-0%
Buck Fire	2,019	29	0	35	0	1-2%	0-0%
Buck Lake Creek	6,080	36	27	107	47	1-2%	0-1%
Burdette Fire	655	0	0	1	1	0-0%	0-0%
Caribou	24,764	820	497	963	587	3-4%	2-2%
Chute Creek	5,107	51	14	68	14	1-1%	0-0%
Conrow	1,807	0	0	291	0	0-16%	0-0%
Crow 2	1,624	170	94	361	200	10-22%	6-12%
Crucifixion Creek	11,010	142	80	494	191	1-4%	1-2%
Cub Creek	5,690	887	495	1,113	609	16-20%	9-11%
Deep Creek	15,900	535	78	1,835	153	3-12%	0-1%
Gibralter Ridge	12,940	335	95	686	161	3-5%	1-1%
Glover Fire	102	0	0	0	0	0-0%	0-0%
Goat Creek	8,298	2,787	1,523	3,829	1,890	34-46%	18-23%
Green Ridge	4,830	46	43	104	77	1-2%	1-2%
Hanover	28,442	693	56	876	134	2-3%	0-0%
Hidden	13,771	6	6	11	6	0-0%	0-0%
Issac Lake	2,453	0	0	1	0	0-0%	0-0%
Liberty Fire	28,686	120	111	411	249	0-1%	0-1%

[1]**Conservative (high susceptibility) and Liberal (mod+high) estimates** provided due to margin of error with species composition and diameter estimates within VMAP data estimating DFB susceptibility.

Resource manager knowledge or ground verification should occur to determine whether the moderate DFB habitat contains abundant ≥ 14" DBH trees to include within DFB suitable habitat totals.

[2]**Severely burnt, DFB susceptible** polygons were excluded from all area calculations based on the Soil Burn Severity and RAVG-hybrid data product (classes 31-34) [NRGG 2017].

[3]**Potential DFB Habitat** refers to susceptible host areas that contained majority Douglas-fir species composition (≥ 50%) with mean tree diameter criteria (mod = 10-13" basal area weighted diameter; high = ≥ 14")

[4]**Probable DFB Habitat** refers to areas with elevated probability of DFB-attack due to moderate burn severity based on the Soil Burn Severity and RAVG-hybrid data product (classes 12, 21, 22 & 13, 14, 23, 24) [NRGG 2017]

Table 1b. Douglas-fir Beetle Suitable Habitat R1 VMap Evaluation within 2017 Wildfires

n **= 23 of 46 total incidents**

Incident	Fire Area (acres)	Conservative Area Estimates[1][2] — DFB Habitat: Potential[3] Highly Susceptible Acres	Conservative Area Estimates[1][2] — DFB Habitat: Probable[4] Highly Susceptible w/ Fire-Injury	Liberal Area Estimates[1][2] — DFB Habitat: Potential[3] Mod+Highly Susceptible Acres	Liberal Area Estimates[1][2] — DFB Habitat: Probable[4] Mod+High Susceptible w/ Fire-Injury	Conservative-Liberal[1][2] Relative Range — DFB Habitat: Potential[3] Conservative - Liberal Range (percent incident area)	Conservative-Liberal[1][2] Relative Range — DFB Habitat: Probable[4] Conservative - Liberal Range (percent incident area)
Little Hogback	34,546	1,908	507	6,076	3,165	6-18%	1-9%
Lolo Peak Fire	53,865	225	44	3,452	1,041	0-6%	0-2%
Lone Pine	14,862	914	534	1,428	779	4-10%	4-5%
Meyers	62,081	84	48	1,208	706	0-2%	0-1%
Monahan	3,614	0	0	72	9	0-2%	0-0%
Moose Creek 1	22,436	2,310	874	2,892	1,074	10-13%	4-5%
Moose Peak	13,909	1,726	537	2,359	768	12-17%	4-6%
NorthForkHughes	3,957	0	0	6	6	0-0%	0-0%
Park Creek	17,982	1,345	848	3,547	2,242	7-20%	5-12%
Patrol Ridge	1,627	79	51	206	131	5-13%	3-8%
Rattlesnake Point	5,130	129	22	198	85	3-4%	0-2%
Reader	106	0	0	1	0	0-1%	0-0%
Reader 2	46	25	0	26	0	54-57%	0-0%
Rice Ridge	160,193	6,918	2,145	15,940	5,170	4-10%	1-3%
Scalp	20,815	35	0	98	0	0-0%	0-0%
Sheep Gap Fire	24,823	1,285	686	5,155	2,354	5-21%	3-9%
Sixty Two	35	6	5	11	5	18-30%	14-14%
Sliderock	900	86	32	341	198	10-38%	4-22%
Strawberry	20,900	9	0	178	32	0-1%	0-0%
Strychnine	1,003	3	0	6	0	0-1%	0-0%
Sunrise Fire	26,291	824	480	3,153	1,934	3-12%	2-7%
Tamarack	414	3	0	3	0	1-1%	0-0%
West Fork	20,083	6,647	1,455	7,923	1,945	33-39%	7-10%

[1] **Conservative (high susceptibility) and Liberal (mod+high) estimates** provided due to margin of error with species composition and diameter estimates within VMAP data estimating DFB susceptibility.

Resource manager knowledge or ground verification should occur to determine whether the moderate DFB habitat contains abundant ≥ 14" DBH trees to include within DFB suitable habitat totals.

[2] **Severely burnt, DFB susceptible** polygons were excluded from all area calculations based on the Soil Burn Severity and RAVG-hybrid data product (classes 31-34) [NRGG 2017].

[3] **Potential DFB Habitat** refers to susceptible host areas that contained majority Douglas-fir species composition (≥ 50%) with mean tree diameter criteria (mod = 10-13" basal area weighted diameter; high = ≥ 14")

[4] **Probable DFB Habitat** refers to areas with elevated probability of DFB-attack due to moderate burn severity based on the Soil Burn Severity and RAVG-hybrid data product (classes 12, 21, 22 & 13, 14, 23, 24) [NRGG 2017]

Table 2a. Douglas-fir Beetle Potential Habitat R1 VMap Evaluation within 2017 Wildfires and Adjacent Two Miles

***n* = 27 of 53 total incidents**

Incident	Incident Area w/ 2-Mile Buffer (acres)	DFB Habitat: Potential[1] Conservative Estimate[2,3] Highly Susceptible Acres	DFB Habitat: Potential[1] Liberal Estimate[2,3] Mod+Highly Susceptible Acres	DFB Habitat: Potential[1] Conservative - Liberal Range[2,3] (percent of buffered area)
Alice Creek	96,063	12,995	30,381	14-32%
Andys Hump	21,185	508	764	2-4%
Ballinger	21,187	1,000	1,707	5-8%
Barren Ridge	23,114	383	810	2-4%
Blacktail Fire	32,691	1,377	3,194	4-10%
Buck Fire	20,693	809	1,068	4-5%
Buck Lake Creek	34,130	302	1,307	1-4%
Burdette Fire	15,236	193	540	1-4%
Caribou	80,714	2,693	4,191	3-5%
Chute Creek	36,976	241	603	1-2%
Conrow	20,694	23	2,273	0-11%
Crow 2	18,809	1,846	2,712	10-14%
Crucifixion Creek	49,243	1,986	8,058	4-16%
Cub Creek	34,600	9,566	11,700	28-34%
Deep Creek	61,321	4,038	10,868	7-18%
Dolly Varden	14,378	0	68	0-0%
Gibralter Ridge	61,036	4,126	7,660	7-13%
Glover Fire	10,702	150	301	1-3%
Goat Creek	35,831	14,181	21,977	40-61%
Green Ridge	45,063	1,732	5,224	4-12%
Hanover	109,320	2,667	3,917	2-4%
Helwick	8,817	1,186	2,934	13-33%
Hidden	59,254	406	1,320	1-2%
Issac Lake	25,070	640	1,787	3-7%
Liberty FIre	87,598	1,492	4,365	2-5%
Little Hogback	95,332	5,493	20,614	6-22%
Lolo Peak Fire	138,465	738	10,121	1-7%

[1] **Potential DFB Habitat** refers to susceptible host areas that contained majority Douglas-fir species composition ($\geq$ 50%) with mean tree diameter criteria (mod = 10-13" basal area weighted diameter; high = $\geq$ 14").

[2] **Conservative** (high susceptibility) and **Liberal** (moderate+high susceptibility) estimates are provided as there is margin of error with species composition and diameter estimates within VMAP data used to represent DFB susceptibility ratings.

[3] **Severely burnt & DFB susceptible** polygons were excluded from all area calculations based on the Soil Burn Severity and RAVG-hybrid data product (classes 31-34) [NRGG 2017] for conservative and liberal susceptibility estimates.

Table 2b. Douglas-fir Beetle Potential Habitat VMAP Evaluation within 2017 Wildfires and Adjacent Two Miles

***n* = 26 of 53 total incidents**

Incident	Incident Area w/ 2-Mile Buffer (acres)	DFB Habitat: Potential[1] Conservative Estimate[2,3] Highly Susceptible Acres	DFB Habitat: Potential[1] Liberal Estimate[2,3] Mod+Highly Susceptible Acres	DFB Habitat: Potential[1] Conservative - Liberal Range[2,3] (percent of buffered area)
Lone Pine	67,416	5,351	7,889	8-12%
Lonesome	8,132	379	646	5-8%
Meyers	164,556	1,890	15,539	1-9%
Monahan	38,817	403	863	1-2%
Moose Creek 1	87,695	7,722	12,421	9-14%
Moose Peak	51,778	8,026	12,325	16-24%
North Fork Hughes	8,882	6	12	0-0%
NorthForkHughes	26,274	106	172	0-1%
Old Man	18,944	287	852	2-4%
Park Creek	63,955	7,016	18,284	11-29%
Patrol Ridge	20,048	1,532	2,689	8-13%
Rattlesnake Point	32,969	1,242	2,436	4-7%
Reader	10,459	3,212	3,728	31-36%
Reader 2	9,651	4,587	5,369	48-56%
Rice Ridge	314,200	30,439	67,741	10-22%
Scalp	84,023	354	1,676	0-2%
Sheep Gap Fire	71,148	3,985	18,646	6-26%
Sixty Two	9,345	837	1,044	9-11%
Sliderock	15,749	3,416	7,987	22-51%
Strawberry	72,944	294	3,778	0-5%
Strychnine	16,041	993	1,918	6-12%
Sunrise Fire	72,326	2,037	8,637	3-12%
Tamarack	13,183	517	609	4-5%
Upper Clear	8,627	1,134	1,956	13-23%
Weasel	27,155	103	1,009	0-4%
West Fork	70,677	18,965	25,371	27-36%

[1]**Potential DFB Habitat** refers to susceptible host areas that contained majority Douglas-fir species composition ($\geq$ 50%) with mean tree diameter criteria (mod = 10-13" basal area weighted diameter; high = $\geq$ 14").

[2]**Conservative** (high susceptibility) and **Liberal** (moderate+high susceptibility) estimates are provided as there is margin of error with species composition and diameter estimates within VMAP data used to represent DFB susceptibility ratings.

[3]**Severely burnt & DFB susceptible** polygons were excluded from all area calculations based on the Soil Burn Severity and RAVG-hybrid data product (classes 31-34) [NRGG 2017] for conservative and liberal susceptibility estimates.

Table 3a. Douglas-fir Beetle Potential Habitat R1 VMap Evaluation within 2017 Wildfires and Adjacent Five Miles
***n* = 27 of 53 total incidents**

Incident	Incident Area w/ 5-Mile Buffer (acres)	DFB Habitat: Potential[1] Conservative Estimate[2,3] Highly Susceptible Acres	DFB Habitat: Potential[1] Liberal Estimate[2,3] Mod+Highly Susceptible Acres	DFB Habitat: Potential[1] Conservative - Liberal Range[2,3] (percent of buffered area)
Alice Creek	208,265	23,084	55,921	11-27%
Andys Hump	79,523	5,387	6,569	7-8%
Ballinger	78,801	2,948	4,667	4-6%
Barren Ridge	83,698	2,268	3,870	3-5%
Blacktail Fire	102,249	4,545	11,141	4-11%
Buck Fire	77,822	3,228	4,887	4-6%
Buck Lake Creek	103,118	2,822	6,119	3-6%
Burdette Fire	66,916	822	3,212	1-5%
Caribou	182,986	4,233	6,074	2-3%
Chute Creek	109,504	939	1,678	1-2%
Conrow	77,853	84	4,947	0-6%
Crow 2	74,076	6,641	10,841	9-15%
Crucifixion Creek	131,756	2,490	13,097	2-10%
Cub Creek	105,412	21,820	36,572	21-35%
Deep Creek	154,815	19,431	35,509	13-23%
Dolly Varden	64,921	59	346	0-1%
Gibralter Ridge	154,614	12,984	23,673	8-15%
Glover Fire	56,682	2,319	3,451	4-6%
Goat Creek	106,130	27,643	49,223	26-46%
Green Ridge	124,950	6,601	16,998	5-14%
Hanover	274,803	7,115	10,744	3-4%
Helwick	52,156	9,227	19,325	18-37%
Hidden	147,296	924	2,751	1-2%
Issac Lake	87,000	4,605	7,252	5-8%
Liberty FIre	192,013	6,208	15,263	3-8%
Little Hogback	203,132	10,453	45,723	5-23%
Lolo Peak Fire	268,456	1,918	17,140	1-6%

[1]**Potential DFB Habitat** refers to susceptible host areas that contained majority Douglas-fir species composition ($\geq$ 50%) with mean tree diameter criteria (mod = 10-13" basal area weighted diameter; high = $\geq$ 14").

[2]**Conservative** (high susceptibility) and **Liberal** (moderate+high susceptibility) estimates are provided as there is margin of error with species composition and diameter estimates within VMAP data used to represent DFB susceptibility ratings.

[3]**Severely burnt & DFB susceptible** polygons were excluded from all area calculations based on the Soil Burn Severity and RAVG-hybrid data product (classes 31-34) [NRGG 2017] for conservative and liberal susceptibility estimates.

Table 3b. Douglas-fir Beetle Potential Habitat R1 VMap Evaluation within 2017 Wildfires and Adjacent Five Miles
***n* = 26 of 53 total incidents**

Incident	Incident Area w/ 5-Mile Buffer (acres)	DFB Habitat: Potential[1] Conservative Estimate[2,3] Highly Susceptible Acres	DFB Habitat: Potential[1] Liberal Estimate[2,3] Mod+Highly Susceptible Acres	DFB Habitat: Potential[1] Conservative - Liberal Range[2,3] (percent of buffered area)
Lone Pine	158,234	11,084	16,698	7-11%
Lonesome	50,469	3,519	5,951	7-12%
Meyers	308,056	4,645	31,093	2-10%
Monahan	115,341	2,663	7,646	2-7%
Moose Creek 1	193,850	14,834	23,133	8-12%
Moose Peak	134,268	18,147	30,290	14-23%
North Fork Hughes	52,317	224	359	0-1%
NorthForkHughes	88,595	437	712	0-1%
Old Man	75,033	2,825	5,271	4-7%
Park Creek	156,006	17,954	44,666	12-29%
Patrol Ridge	76,808	3,536	7,041	5-9%
Rattlesnake Point	102,316	5,408	9,003	5-9%
Reader	56,108	18,259	21,716	33-39%
Reader 2	54,183	20,001	23,151	37-43%
Rice Ridge	521,517	50,911	112,150	10-22%
Scalp	193,442	744	6,533	0-3%
Sheep Gap Fire	164,687	10,430	44,890	6-27%
Sixty Two	53,438	5,012	6,756	9-13%
Sliderock	67,835	15,838	32,743	23-48%
Strawberry	172,728	988	7,805	1-5%
Strychnine	68,534	3,973	8,506	6-12%
Sunrise Fire	167,088	4,674	22,469	3-13%
Tamarack	62,319	1,528	2,110	2-3%
Upper Clear	51,695	4,754	16,042	9-31%
Weasel	90,744	476	3,781	1-4%
West Fork	168,530	33,220	44,360	20-26%

[1]**Potential DFB Habitat** refers to susceptible host areas that contained majority Douglas-fir species composition ($\geq$ 50%) with mean tree diameter criteria (mod = 10-13" basal area weighted diameter; high = $\geq$ 14").

[2]**Conservative** (high susceptibility) and **Liberal** (moderate+high susceptibility) estimates are provided as there is margin of error with species composition and diameter estimates within VMAP data used to represent DFB susceptibility ratings.

[3]**Severely burnt & DFB susceptible** polygons were excluded from all area calculations based on the Soil Burn Severity and RAVG-hybrid data product (classes 31-34) [NRGG 2017] for conservative and liberal susceptibility estimates.

Table 4a. Total Area by DFB Susceptibility Class and RAVG+SBS Burn Severity Groups for select 2017 Wildfire Incidents > 15,000 acres

	DFB Hazard Class	Caribou	Deep Creek	Liberty Fire	Little Hogback	Little Hogback	Lolo Peak	Meyers	Meyers	Rice Ridge	Rice Ridge	Sheep Gap	Sunrise	West Fork
UnBurned	Mod	0			0	0	0		6	0	0	2	1	0
Green, no fire-injury: potential DFB habitat	High									3			1	3
Group0: RAVG+SBS 11	Mod	53	1,225	153	1,049	460	2,229	15	442	5,580	416	2,200	894	757
Green, minimal fire-injury: potential DFB habitat	High	323	456	9	1,388	13	182	27	9	4,770		599	361	5,178
Group1: RAVG+SBS 12,21,22	Mod	90	70	138	468	2,181	966	40	563	2,572	120	1,592	1,353	490
Green, fire-injured: potential & probable DFB habitat	High	497	51	110	506	1	44	37	1	1,909	32	678	471	1,452
Group2: RAVG+SBS 13,14,23,24	Mod		5		0	8	31	7	48	315	17	77	107	
Brown, fire-injured: potential & probable DFB habitat	High		27	1				10		199	6	8	10	1
Group3: RAVG+SBS 31,32,33,34	Mod	547	287	547	536	2,557	2,549	720	3,232	11,072	1924	3,751	824	540
Black, fire-killed: No potential or probable DFB habitat	High	599	268	209	506		64	1,042	90	9,324	118	733	184	1,337
Liberal Estimate: DFB Susceptible (Mod+High) Acre Totals incorporating all UnBurned & RAVG+SBS Classes		2,109	2,390	1,167	4,454	5,220	6,065	1,899	4,392	35,744	2703	9,640	4,206	9,757
Conservative Estimate: DFB Susceptible (High only) Acre Totals incorporating UnBurned & only RAVG+SBS Classes 11-24 (excluding fire-killed classes)		820	535	120	1,895	13	226	74	10	6,877	156	1,285	842	6,630
Total Incident Acres		24,764	15,900	28,686	34,546		53,865	62,023		160,193		24,823	26,797	19,508

Table 4b. Total Area by DFB Susceptibility Class and RAVG+SBS Burn Severity Groups for select 2017 Wildfire Incidents < 15,000 acres

	DFB Hazard Class	Black	Buck	Burdette	Cub Creek	Gibraltar Ridge	Gibraltar Ridge	Goat Creek	Green Ridge	Monahan	Moose Peak	Nelson Creek	North Fork Hughes	Reader2	Reader Fire	Sliderock	Sliderock	Weasel
UnBurned	Mod	151	5						5			1		1	1			
Green, no fire-injury: potential DFB habitat	High	77	29						3					25				
Group0: RAVG+SBS class 11	Mod				112	264	20	674	18	64	287					81	7	
Green, minimal fire-injury: potential DFB habitat	High				392	240		1,264	0		1,145					54		
Group1: RAVG+SBS class 12,21,22	Mod			1	111	49	18	366	33	9	217		6			163	3	
Green, fire-injured: potential & probable DFB habitat	High				480	95		1,523	42		468					32		
Group2: RAVG+SBS class 13,14,23,24	Mod				3			2	2		9							
Brown, fire-injured: potential & probable DFB habitat	High				15				0		69							
Group3: RAVG+SBS class 31,32,33,34	Mod			6	18	11	98	308	72		361					44		3
Black, fire-killed: No potential or probable DFB habitat	High				57	23	1	672	9		741							
Liberal Estimate: DFB Susceptible (Mod+High) Acre Totals incorporating all UnBurned & RAVG+SBS Classes		228	35	7	1,187	681	137	4,809	185	72	3,296	1	6	26	1	375	11	3
Conservative Estimate: DFB Susceptible (High only) Acre Totals incorporating UnBurned & only RAVG+SBS Classes 11-24 (excluding fire-killed classes)		0	0	0	886	335	1	2,787	43	0	1,682	0	0	0	0	86	-	0
Total Incident Acres		1,893	2,019	655	5,690	12,940		8,298	4,830	3,613	12,630	280	3,934	46	106	900		3,856

Note: Orange highlighting denotes aggregations of high DFB-susceptible habitat and partially burned areas that are >1,000 (individual Groups or Sum), where over 20% of the burn area is in moderate or high susceptibility classes regardless of burn severity (darker highlights), or where area that is highly susceptible and burned (but not destroyed) is greater than 30%. Also note in Tables 4a and 4b, habitat estimates based on older R1 VMap product fields (different query for DFB susceptibility) are written in purple.

Table 4c. Relative Percent of Area by DFB Susceptibility Class and RAVG+SBS Burn Severity Groups for 2017 Wildfire Incidents > 15,000 acres

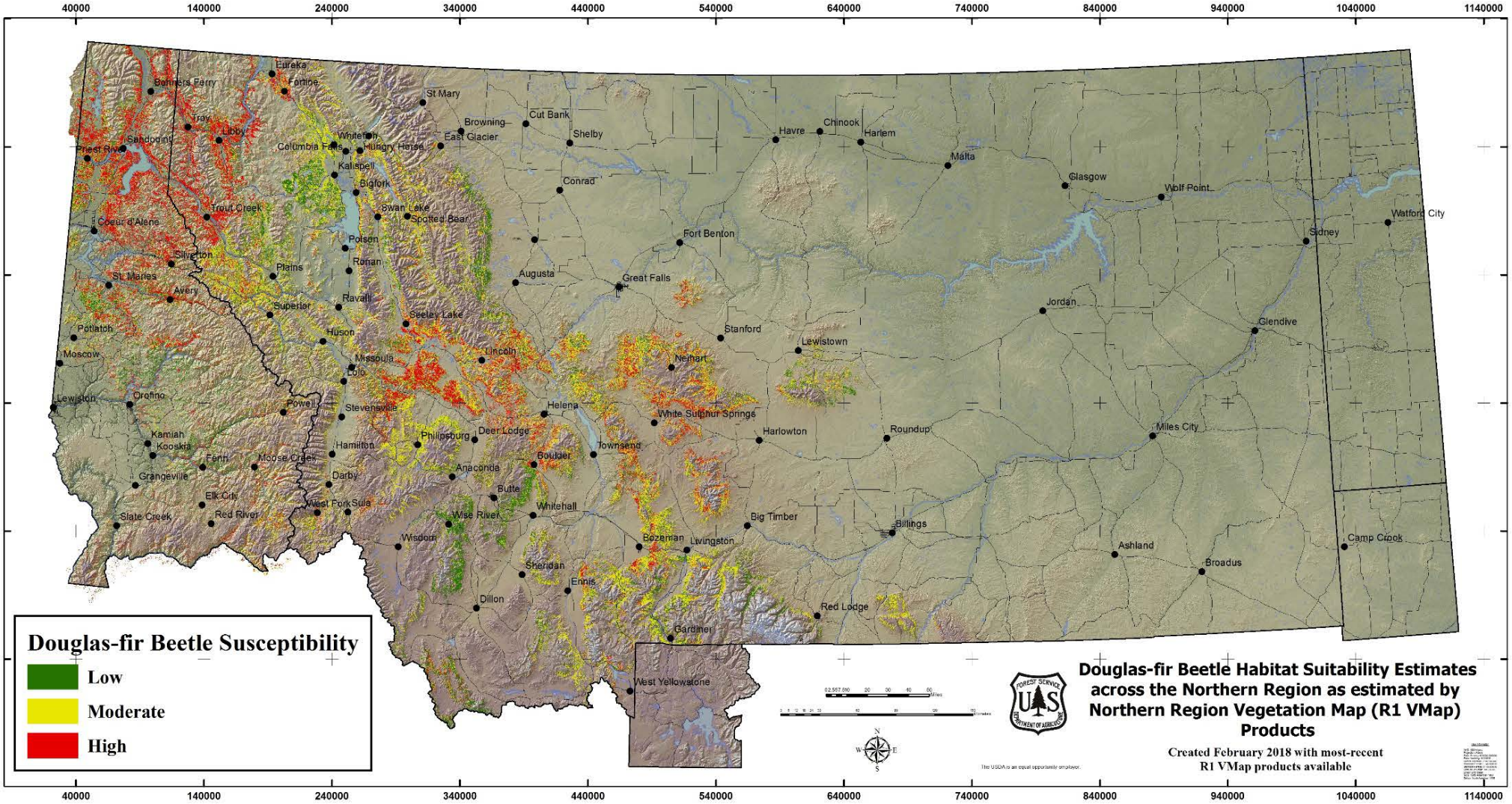
	DFB Hazard Class	Caribou	Deep Creek	Liberty Fire	Little Hogback	Lolo Peak	Meyers	Rice Ridge	Sheep Gap	Sunrise	West Fork
UnBurned	Mod	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Green, no fire-injury: potential DFB habitat	High	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Group0: RAVG+SBS class 11	Mod	0.2%	7.7%	0.5%	4.4%	4.1%	0.7%	3.7%	8.9%	3.3%	3.9%
Green, minimal fire-injury: potential DFB habitat	High	1.3%	2.9%	0.0%	4.1%	0.3%	0.1%	3.0%	2.4%	1.3%	26.5%
Group1: RAVG+SBS class 12,21,22	Mod	0.4%	0.4%	0.5%	7.7%	1.8%	1.0%	1.7%	6.4%	5.0%	2.5%
Green, fire-injured: potential & probable DFB habitat	High	2.0%	0.3%	0.4%	1.5%	0.1%	0.1%	1.2%	2.7%	1.8%	7.4%
Group2: RAVG+SBS class 13,14,23,24	Mod	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%	0.0%
Brown, fire-injured: potential & probable DFB habitat	High	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
Group3: RAVG+SBS class 31,32,33,34	Mod	2.2%	1.8%	1.9%	9.0%	4.7%	6.4%	8.1%	15.1%	3.1%	2.8%
Black, fire-killed: Not potential or probable DFB habitat	High	2.4%	1.7%	0.7%	1.5%	0.1%	1.8%	5.9%	3.0%	0.7%	6.9%
Liberal Estimate: Percent of Fire Incident with DFB Susceptible (Mod+High) Acres incorporating all UnBurned & RAVG+SBS Classes		8.5%	15.0%	4.1%	28.0%	11.3%	10.1%	24.0%	38.8%	15.7%	50.0%
Conservative Estimate: Percent of Fire Incident with DFB Susceptible (High only) Acres incorporating UnBurned & only RAVG+SBS Classes 11-24 (excluding fire-killed classes)		3.3%	3.4%	0.4%	5.5%	0.4%	0.1%	4.3%	5.2%	3.1%	34.0%

Table 4d. Relative Percent of Area by DFB Susceptibility Class and RAVG+SBS Burn Severity Groups for 2017 Wildfire Incidents < 15,000 acres

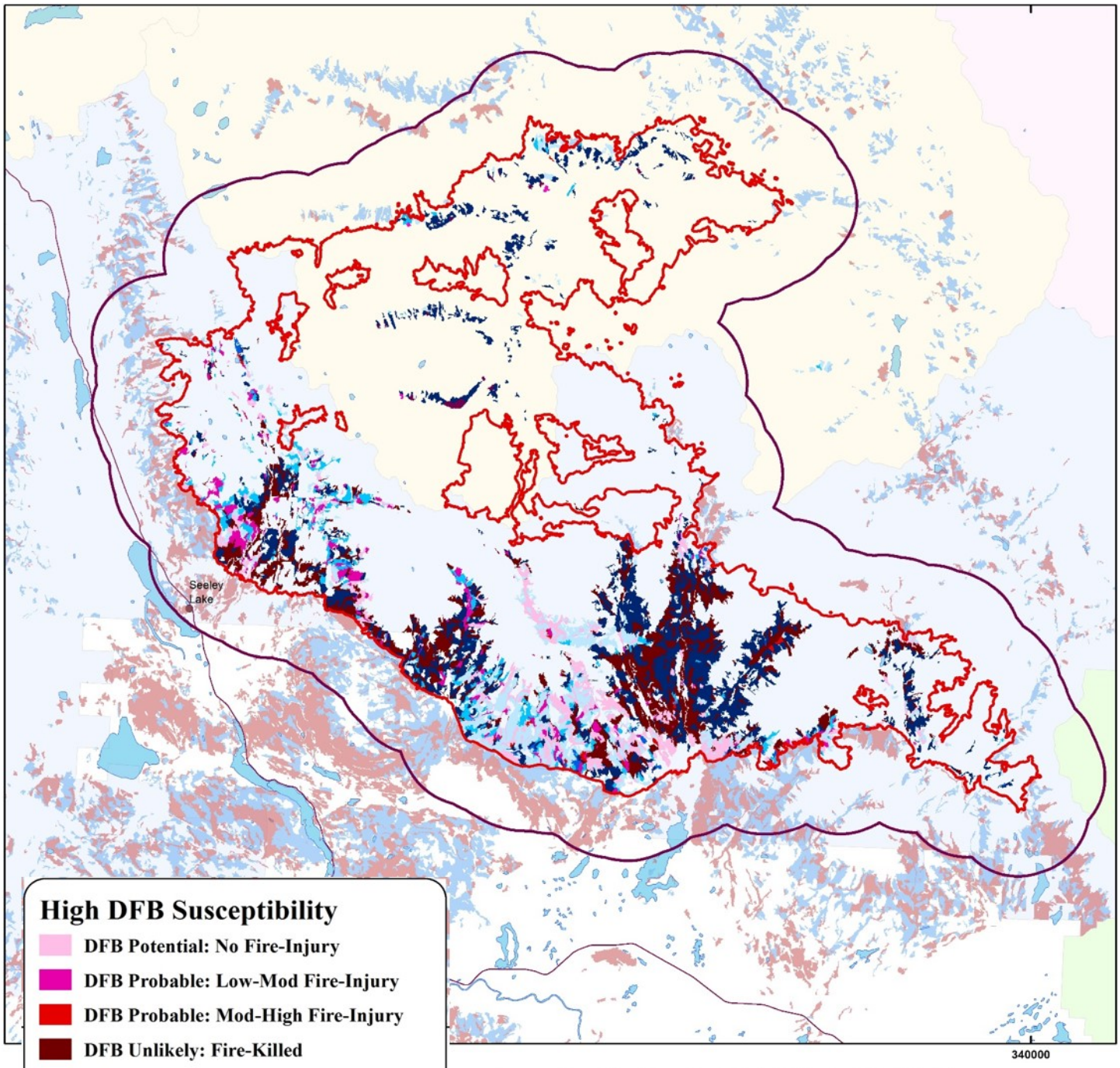
	DFB Hazard Class	Black	Buck	Burdette	Cub Creek	Gibraltar Ridge	Goat Creek	Green Ridge	Monahan	Moose Peak	Nelson Creek	North Fork Hughes	Reader2	Reader Fire	Sliderock	Weasel
UnBurned	Mod	8.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.5%	0.0%	2.8%	0.7%	0.0%	0.0%
Green, no fire-injury: potential DFB habitat	High	4.1%	1.4%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	54.2%	0.1%	0.0%	0.0%
Group0: RAVG+SBS class 11	Mod	0.0%	0.0%	0.0%	2.0%	2.2%	8.1%	0.4%	1.8%	2.3%	0.0%	0.0%	0.0%	0.0%	9.8%	1.8%
Green, minimal fire-injury: potential DFB habitat	High	0.0%	0.0%	0.0%	6.9%	1.9%	15.2%	0.0%	0.0%	9.1%	0.0%	0.0%	0.0%	0.0%	6.1%	0.0%
Group1: RAVG+SBS class 12,21,22	Mod	0.0%	0.0%	0.2%	2.0%	0.5%	4.4%	0.7%	0.2%	1.7%	0.0%	0.2%	0.0%	0.0%	18.5%	0.2%
Green, fire-injured: potential & probable DFB habitat	High	0.0%	0.0%	0.0%	8.4%	0.7%	18.3%	0.9%	0.0%	3.7%	0.0%	0.0%	0.0%	0.0%	3.5%	0.0%
Group2: RAVG+SBS class 13,14,23,24	Mod	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Brown, fire-injured: potential & probable DFB habitat	High	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Group3: RAVG+SBS class 31,32,33,34	Mod	0.0%	0.0%	0.8%	0.3%	0.8%	3.7%	1.5%	0.0%	2.9%	0.0%	0.0%	0.0%	0.0%	4.9%	0.0%
Black, fire-killed: No potential or probable DFB habitat	High	0.0%	0.0%	0.0%	1.0%	0.2%	8.1%	0.2%	0.0%	5.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Liberal Estimate: Percent of Fire Incident with DFB Susceptible (Mod+High) Acres incorporating all UnBurned & RAVG+SBS Classes		12.0%	1.7%	1.1%	20.9%	6.3%	57.9%	3.8%	2.0%	26.1%	0.5%	0.2%	57.0%	0.8%	42.8%	2.0%
Conservative Estimate: Percent of Fire Incident with DFB Susceptible (High only) Acres incorporating UnBurned & only RAVG+SBS Classes 11-24 (excluding fire-killed classes)		0.0%	0.0%	0.0%	15.6%	2.6%	33.6%	0.9%	0.0%	13.3%	0.0%	0.0%	0.0%	0.0%	9.6%	0.0%

Note: Orange highlighting denotes aggregations of high DFB-susceptible habitat and partially burned areas that are >1,000 (individual Groups or Sum), where over 20% of the burn area is in moderate or high susceptibility classes regardless of burn severity (darker highlights), or where area that is highly susceptible and burned (but not destroyed) is greater than 30%. Also note in Tables 4a and 4b, habitat estimates based on older R1 VMap product fields (different query for DFB susceptibility) are written in purple.

Map 1. Douglas-fir Beetle Habitat Suitability across the Northern Region Estimated with R1 VMap Products



Map 2: Rice Ridge Wildfire Incident



High DFB Susceptibility

- DFB Potential: No Fire-Injury
- DFB Probable: Low-Mod Fire-Injury
- DFB Probable: Mod-High Fire-Injury
- DFB Unlikely: Fire-Killed

Moderate DFB Susceptibility

- DFB Potential: No Fire-Injury
- DFB Probable: Low-Mod Fire-Injury
- DFB Probable: Mod-High Fire-Injury
- DFB Unlikely: Fire-Killed

DFB Susceptibility Outside Fire

- Moderate Susceptibility
- High Susceptibility
- 2-Mile Buffer of Fire Perimeter

Douglas-fir Beetle (DFB) Suitable Habitat VMAP Evaluation within and near the Rice Ridge Fire on the Lolo (blue), Flathead (yellow) and Helena (green) NFs

Map Created by Region 1
State and Private Forestry
Forest Health Protection
February 1st, 2018

N
W E
S

0 0.5 1 1.5 2 4 6 8 10 12 Miles

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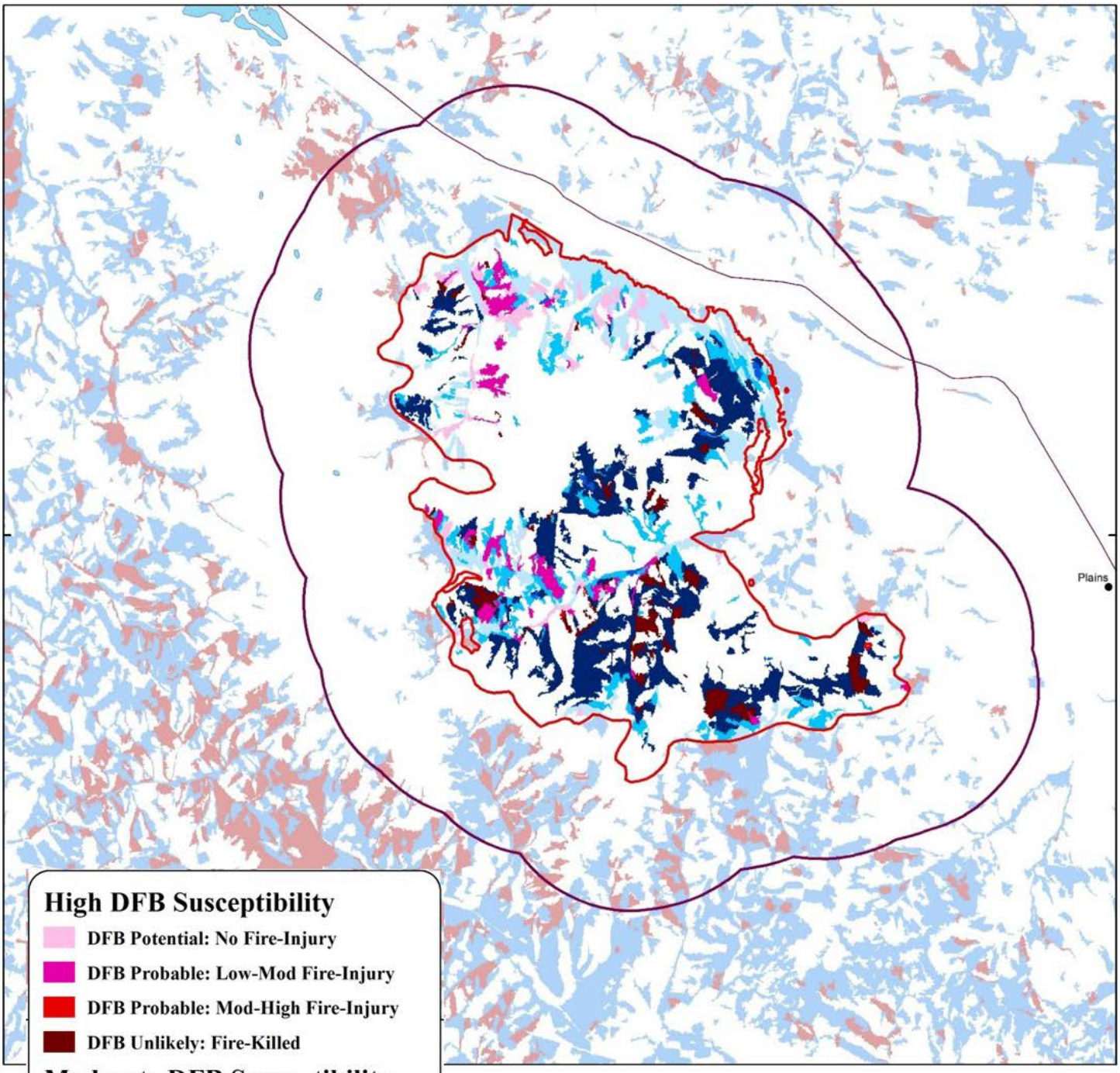
Map 3: Sheep Gap Wildfire Incident



High DFB Susceptibility

- DFB Potential: No Fire-Injury
- DFB Probable: Low-Mod Fire-Injury
- DFB Probable: Mod-High Fire-Injury
- DFB Unlikely: Fire-Killed

Moderate DFB Susceptibility

- DFB Potential: No Fire-Injury
- DFB Probable: Low-Mod Fire-Injury
- DFB Probable: Mod-High Fire-Injury
- DFB Unlikely: Fire-Killed

DFB Susceptibility Outside Fire

- Moderate Susceptibility
- High Susceptibility
- 2-Mile Buffer of Fire Perimeter

Douglas-fir Beetle (DFB) Suitable Habitat VMAP Evaluation within and near the Sheep Gap Fire, Lolo National Forest

Map Created by Region 1
State and Private Forestry
Forest Health Protection
February 1st, 2018

N
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0 0.5 1 1.5 2 4 6 Miles

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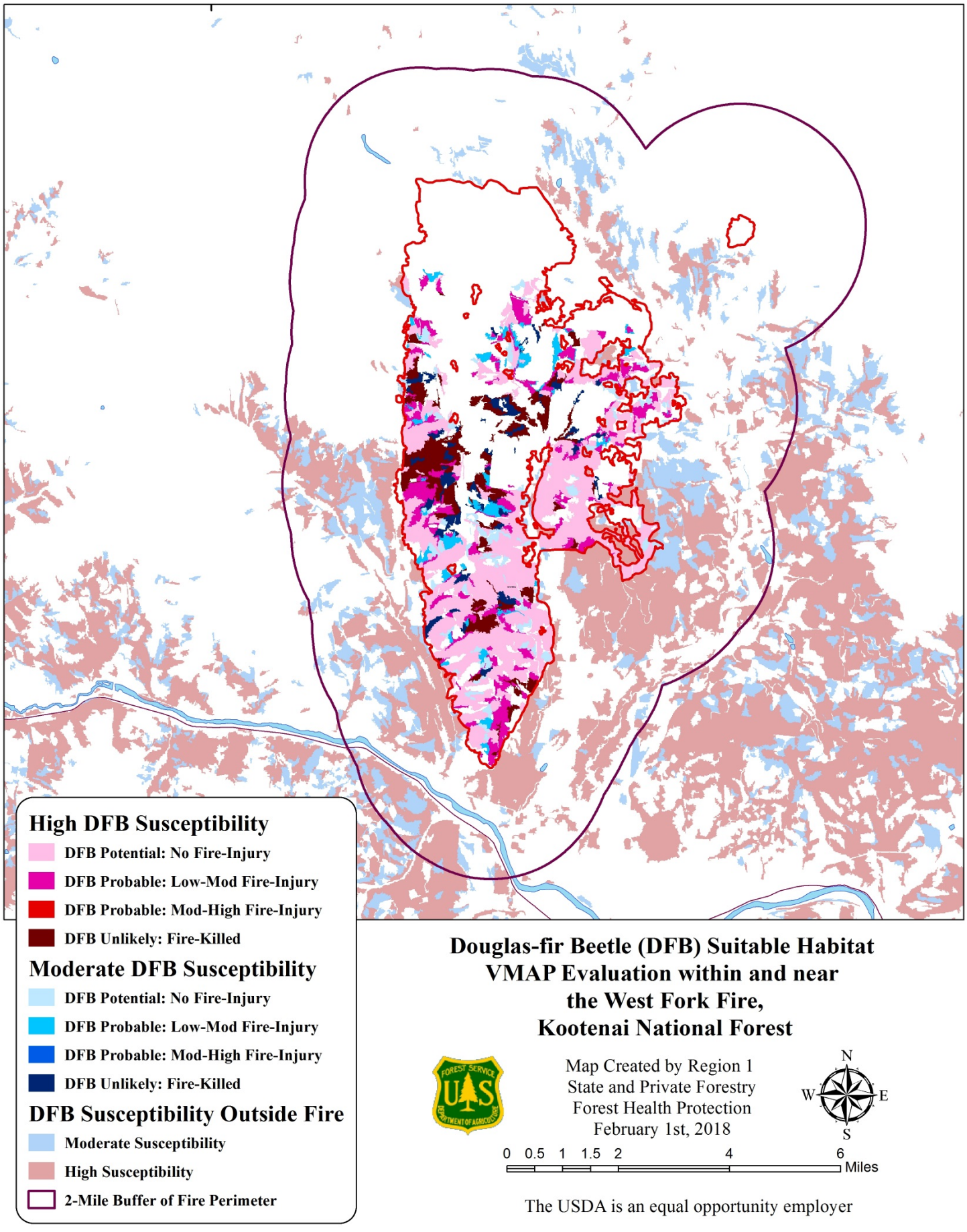
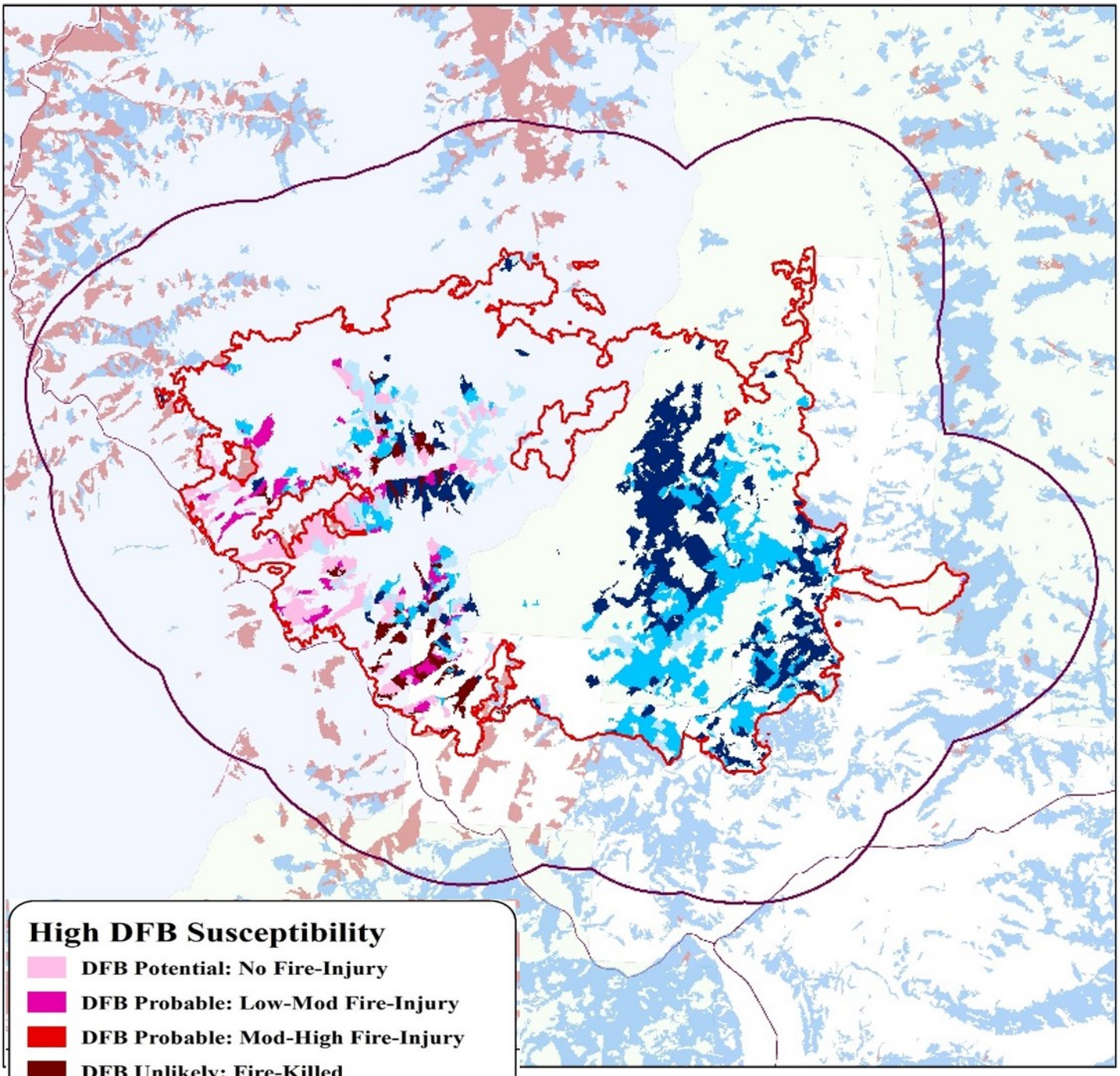
Map 4: West Fork Wildfire Incident



Map 5: Little Hogback Wildfire Incident



High DFB Susceptibility
- DFB Potential: No Fire-Injury
- DFB Probable: Low-Mod Fire-Injury
- DFB Probable: Mod-High Fire-Injury
- DFB Unlikely: Fire-Killed

Moderate DFB Susceptibility
- DFB Potential: No Fire-Injury
- DFB Probable: Low-Mod Fire-Injury
- DFB Probable: Mod-High Fire-Injury
- DFB Unlikely: Fire-Killed

DFB Susceptibility Outside Fire
- Moderate Susceptibility
- High Susceptibility
- 2-Mile Buffer of Fire Perimeter

Douglas-fir Beetle (DFB) Suitable Habitat
VMAP Evaluation within and near
the Little Hogback Fire,
Lolo (blue) and B-D (green) National Forests

Map Created by Region 1
State and Private Forestry
Forest Health Protection
February 1st, 2018

N
W E
S

0 0.5 1 1.5 2 4 6 Miles

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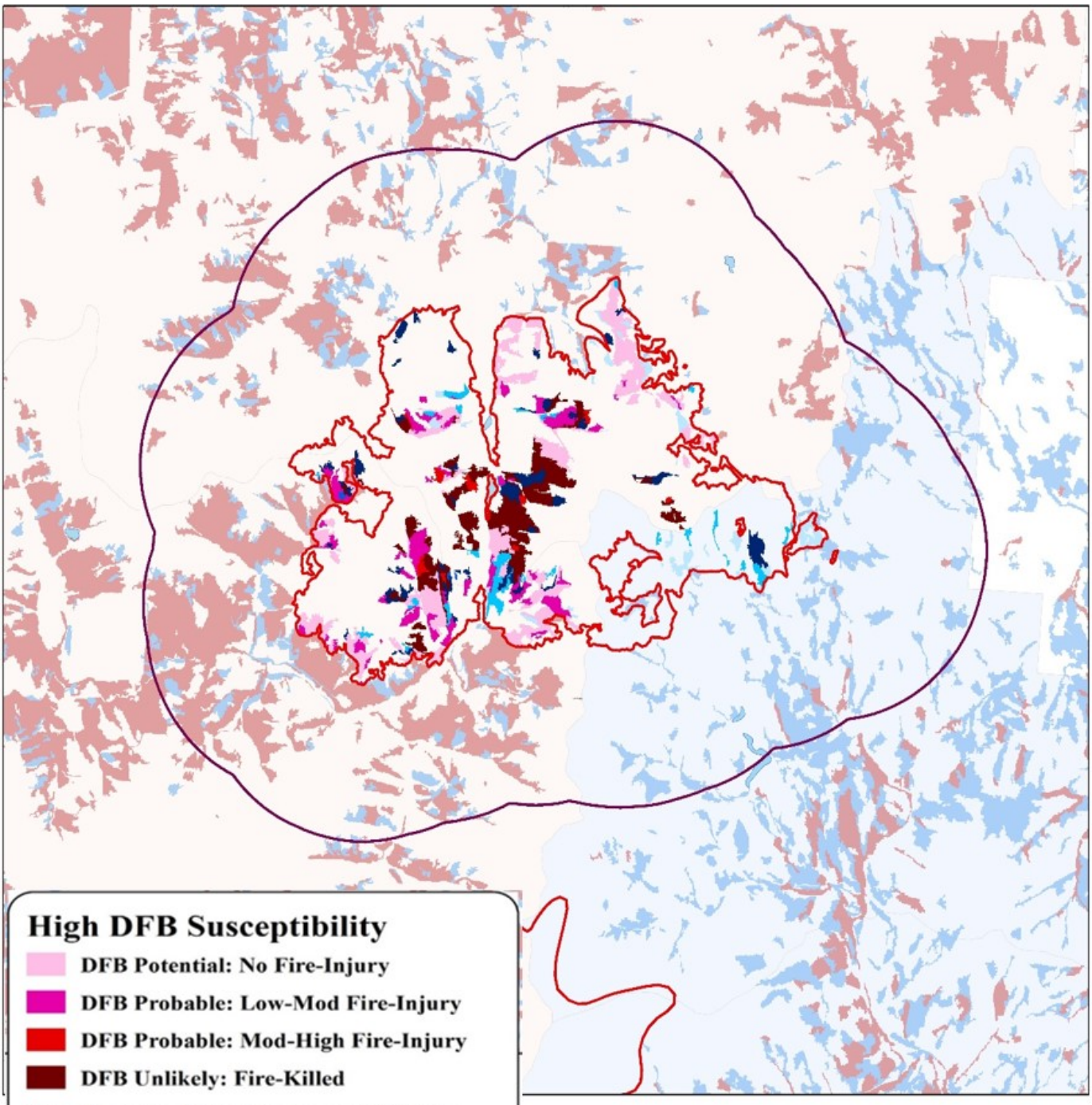
Map 6: Moose Creek Wildfire Incident



High DFB Susceptibility

- DFB Potential: No Fire-Injury
- DFB Probable: Low-Mod Fire-Injury
- DFB Probable: Mod-High Fire-Injury
- DFB Unlikely: Fire-Killed

Moderate DFB Susceptibility

- DFB Potential: No Fire-Injury
- DFB Probable: Low-Mod Fire-Injury
- DFB Probable: Mod-High Fire-Injury
- DFB Unlikely: Fire-Killed

DFB Susceptibility Outside Fire

- Moderate Susceptibility
- High Susceptibility
- 2-Mile Buffer of Fire Perimeter

Douglas-fir Beetle (DFB) Suitable Habitat VMAP Evaluation within and near the Moose Creek Fire, Kootenai (tan) and Lolo (blue) NFs

Map Created by Region 1
State and Private Forestry
Forest Health Protection
February 1st, 2018

N
W E
S

0 0.5 1 1.5 2 4 Miles

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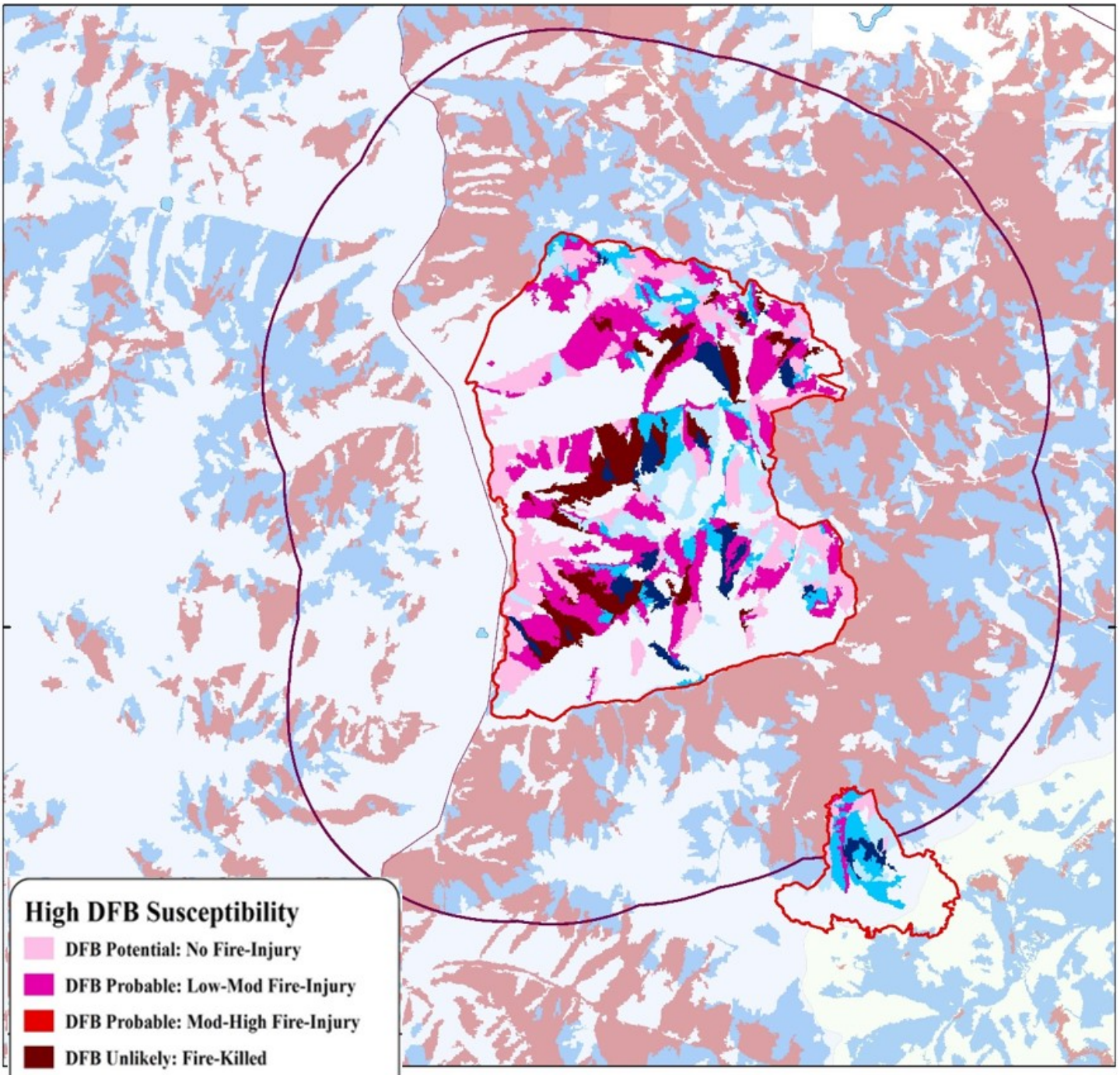
Map 7: Goat Creek Wildfire Incident and adjacent Slide Rock Wildfire Incident



High DFB Susceptibility
- DFB Potential: No Fire-Injury
- DFB Probable: Low-Mod Fire-Injury
- DFB Probable: Mod-High Fire-Injury
- DFB Unlikely: Fire-Killed

Moderate DFB Susceptibility
- DFB Potential: No Fire-Injury
- DFB Probable: Low-Mod Fire-Injury
- DFB Probable: Mod-High Fire-Injury
- DFB Unlikely: Fire-Killed

DFB Susceptibility Outside Fire
- Moderate Susceptibility
- High Susceptibility
- 2-Mile Buffer of Fire Perimeter

Douglas-fir Beetle (DFB) Suitable Habitat VMAP Evaluation within and near the Goat Creek (and Slide Rock) Fire, Lolo (and B-D) National Forests

Map Created by Region 1
State and Private Forestry
Forest Health Protection
February 1st, 2018

N W E S

0 0.5 1 1.5 2 4 Miles

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Pertinent experimental research assessing bark beetle[a] activity in fire-injured trees

Note: Table was created from a 2011 literature review and further studies detailing beetle activity in fire-injured trees have been published since table creation

Location	Reps	Time Period	Beetle Species (Burn Treatment vs Non-Burned Units)	Study Findings	Literature cited
Northern CA - Lake Tahoe Basin	5	1997-1998	JPB in PIJE[b] (5 vs 1% of all host attacked); RTB (23 vs 0%); *Ips* (9 vs 0%)	1 year post-Rx burn: burn trees 24.8 times more likely attacked by JPB, *Ips*, and/or RTB than unburned; Significant JPB attack variables: % crown scorch, % live crown, bole char height, soil burn severity	Bradley and Tueller 2001
Northern CA - Teakettle Experimental Forest	9[c]	2001-2004	MPB in PILA[b] (7-13 vs 2-3% treatment range for mean % of all host attacked); JPB (5-13 vs 2-6%); RTB (5-8 vs 1-3%), FEN (12-18 vs 3-12%)	3 year post-Rx burn bark beetle-attacks higher in burned units for JPB, MPB, FEN, RTB. Mortality skewed toward larger-diameter (>25 in. DBH) Jeffrey and sugar pines with basal fire-injury	Maloney et al. 2008
Northeastern CA - Blacks Mtn Experimental Forest	4[c]	1999-2002	MPB in PIPO[b] (0.7 vs 0.2% of all host attacked); WPB (1% vs 0.1%); FEN (3 vs 1%); *Ips* (0.8 vs <0.1%); all beetles (2.6 vs 0.3%)	2 year post-Rx burn bark beetle-attacks higher in burned units for WPB, MPB, FEN, & *Ips*. Mortality was not skewed towards larger diameter trees but was skewed towards white fir (47.6% of all mortality).	Fettig et al. 2008
Central CA - Sequoia National Park	3	2002-2006	MPB/WPB/JPB in *Pinus* (0.45 spring burn and 0.49 fall burn vs 0.16 non-burned probability of beetle attack) FEN in *Abies* (0.26 & 0.12 vs 0.02)	3 year post-Rx burn attacks higher in burned units for MPB, WPB, and RTB. Given attack, mortality skewed toward smaller-diameter (<16 in. DBH) fir but not skewed in sugar pines. Burn season did not affect *Pinus* attacks & inconclusive for *Abies*.	Schwilk et al. 2006
Northern CA - Tahoe National Forest	3	2004-2008	Fire+bark beetles+other mortality agents (15% spring and 16% fall burn vs 0.3% non-burned total tree mortality)	3 year post-Rx Spring vs Fall burning had similar fire/bark beetle/other-caused tree mortality. WPB-caused greater large-diameter (>20 in. DBH) PIPO mortality in Spring [but not Fall] vs Non-burned units. Tree mortality (by all agents) skewed towards smaller (<8 in. DBH) trees.	Fettig et al. 2010b
Sierra-Nevada Mtn. Wildfires: McNally, Power, Cone, etc.	N/A[f]	2002-2009[g]	Non-burned area not surveyed; 82% of post-wildfire PILA mortality in Power Fire was associated with MPB attack	5-year post-fire variables that influenced probability of mortality after wildfire varied by species and included: % live crown kill, DBH, cambium kill, presence of RTB attack (*Pinus* only).	Hood et al. 2010
Southern Cascade Mtns., Klamath National Forest	3	2001-2005	MPB/WPB/*Ips* spp. in *Pinus* and FEN in ABCO[b] (9 vs 3% bark beetle-caused tree mortality)[h]	4-year post-fire majority (≈74.9% of all trees, ≈58.6 of all pine, & ≈85.2% of all fir) of all bark beetle-caused tree mortality occurred in Rx burn (burn only & thin+burn) units. Tree mortality was skewed toward small diameter pine and fir.	Fettig et al. 2010a
AZ and NM - Four National Forests	4	2003-2006	*Dendroctonus*[d] & *Ips* spp. (13 vs 2% of all trees attacked); (8 vs 0.3% of all trees successfully attacked); (8.4 vs 0.6% total tree mortality)	3 year post-Rx burn attacks increased with crown damage. Mortality not skewed to certain DBH class. Best mortality predictors was crown scorch with bark beetle attack rating & bole char severity also significant.	Breece et al. 2008
Northern AZ	3	1995-1999	Non-burned area not surveyed; PIPO mortality likely at 70-80% crown damage w/ no insect attacks; RTB-attacked PIPO had 74%, 68%, & 48% survival rates 3 years post-burn	3 year post-Rx burn & wildfire variables that influenced PIPO probability of mortality (Pm) after wildfire: % crown damage (scorch+consumption) and *Dendroctonus/Ips* attack severity (none, partial, & mass-attacks).	McHugh et al. 2003
Northern Rocky Mnts - WY and MT	3[e]	2001-2004	Non-burned area not surveyed; 95% of DFB attacks were in fire-injured trees	Variables that influenced DFB probability of attack: DBH, SDI, % live crown kill, & cambium necrosis. Excluding SDI, previous variables with beetle presence/absence were used to assess probability of mortality in fire-injured trees.	Hood and Bentz 2007

[a] Bark beetle accronyms: JPB = *Dendroctonus jeffreyi*; MPB = *D. ponderosae*; WPB = *D. brevicomis*; RTB = *D. valens*; DFB = *D.* FEN = *Scolytus ventralis*; *Ips* = *Ips* spp.

[b] Tree Species accronyms: PIJE = *Pinus jeffreyi*; PILA = *P. lambertiana*; PIPO = *P. ponderosa*; ABCO = *Abies concolor*; tree species not distinguished are specific to the attacking bark beetle in that region

[c] Reps refer to burn vs non-burn treatments; imbedded thinning treatments also exist

[d] > 80% of trees in study area were attacked by >1 species of bark beetles; *Dendroctonus* spp. included: WPB, RTB, *D. frontalis*, & *D. adjunctus*; *Ips* spp. included: *I. latidens, I. lecontei,* & *I. calligraphus*

[e] Three fires were surveyed with 79 plots

[f] Data from five fires collapsed to calculate probability of mortality for > 10,000 individual trees of various species

[g] Time period surveyed varied for each fire sampled

[h] Comparison refers to burn only unit vs control cummulative 4 years post-burn; Thin+burn unit (3.3% total bark beetle-caused tree mortality) did not differ from control; majority of mortality caused in MPB in PIPO

Appendix A

Appendix A: Works Cited

Bradley, T. and P. Tueller, 2001. **Effects of fire on bark beetle presence on Jeffrey pine in the Lake Tahoe Basin**. Forest Ecology and Management. 142, 205-214.

Breece, C., Kolb, T., Dickson, B., McMillin, J., Clancy, K. 2008. **Prescribed fire effects on bark beetle activity and tree mortality in southwestern ponderosa pine forests**. Forest Ecology and Management. 255, 119-128.

Fettig, C., Borys, R., McKelvey, S., Dabney, C. 2008. **Blacks Mountain Experimental Forest: bark beetle responses to differences in forest structure and the application of prescribed fire in interior ponderosa pine**. Canadian Journal of Forest Research. 38, 924-935.

Fettig, C., Borys, R., Dabney, C. 2010a. **Effects of Fire and Fire Surrogate Treatments on Bark Beetle-Caused Tree Mortality in Southern Cascades, California**. Forest Science. 56(1), 60-73.

Fettig, C.J., et. al. 2010b. **Effects of prescribed fire and season of burn on direct and indirect levels of tree mortality in ponderosa and Jeffrey pine forests in California, USA**. Forest Ecology and Management 260: 207-218.

Hood, S. and B. Bentz. 2007. **Predicting postfire Douglas-fir beetle attacks and tree mortality in the Northern Rocky Mountains**. Canadian Journal of Forest Research. 37, 1058-1069.

Hood, S., Smith, S., Cluck, D. 2010. **Predicting Mortality for Five California Conifers Following Wildfire**. Forest Ecology and Management 260: 750-762.

Maloney, P., Smith, T., Jensen, C., Innes, J., Rizzo, D., North, M., 2008. **Initial tree mortality and insect and pathogen response to fire and thinning restoration treatments in an old-growth mixed-conifer forest of the Sierra Nevada, California**. Canadian Journal of Forest Research. 38, 3011-3020.

McHugh, C., Kolb, T., Wilson, J. 2003. **Bark Beetle Attacks on Ponderosa Pine Following Fire in Northern Arizona**. Environmental Entomology. 32(3), 510-522.

Shwilk, D., Knapp, E., Ferrenberg, S., Keeley, J., Caprio, A. 2006. **Tree mortality from fire and bark beetles following early and late season prescribed fires in a Sierra Nevada mixed-conifer forest**. Forest Ecology and Management. 232, 36-45.

Appendix B. Geospatial Analysis Methods & Validation:

Specific data analysis/query methods were assessed for best-available geospatial information to provide estimates of DFB potential and probable habitat. These estimates were based on coarse-level data and local resource manager expertise and/or field validation should occur to ensure data reasonably represent species, diameter, and burn severity estimations.

Suitable Habitat with a Potential for DFB Colonization

Data source: Latest updated Northern Region R1 VMap product available as of 1/5/18. Examples: Beaverhead-Deerlodge NF VMap v11, Bitterroot-Lolo NF VMap v16, Kootenai-Idaho Panhandle NF VMap v17

Query criteria for R1 VMap products:

1) DF host basal area percent composition >= 50% ; AND

2) Basal area weighted average tree diameter:
    a. High susceptibility is >= 14" DBH; Moderate is 10-13" DBH; Low is <10" DBH

3) For R1 VMap products that haven't had % species basal area percent composition or basal area weighted average tree diameter attributed to polygons, then Dominance Type 40% Plurality and Tree Size classes were used:
    a. Species dominance criteria: Dom40 Basal Area = Mx-PSME ; AND
    b. High susceptibility is tree diameter size class >15" DBH; Moderate is 10-15" class; Low is <10" classes

Note: basal area and/or stand density index attributes are not modeled in R1 VMap products; thus, stand density-related DFB susceptibility criteria were not incorporated into analysis. Canopy cover is modeled; however, this attribute was not utilized as a proxy for stand density as 1) it can have variable relationship with basal area based on forest structure and 2) coarse-level validation indicated reasonable results without added complexity of this proxy.

Coarse-level Validation of Suitable DFB Habitat with Forest Inventory and Analysis Subplot Data

Data source: Forest Inventory and Analysis (FIA) subplot data that occurred within 2017 wildfire incidents that contained numerous FIA subplots within fire perimeters: Hanover, Little Hogback, Lolo Peak, Meyers, Rice Ridge, and Scalp incidents. Incidents spanned 310,627 acres and contained 233 FIA subplots.

Methods: FIA subplot data located within 2017 fire perimeters were attributed with DFB hazard/susceptibility ratings as defined in Randall et al. (2011) based on field-level tree measurements from most-recent sample date. Then, the percent of total FIA subplots with moderate+high susceptibility ratings were compared to the percent of total DFB suitable habitat area (mod+high) within fire perimeters estimated from R1 VMap products.

Findings: Sampled FIA subplots indicate 24% of total area within incidents that spanned was moderate or highly susceptible to DFB vs 19% of combined incident areas estimated from R1 VMap product analysis. This validation based of best-available data suggests R1 VMap susceptibility estimates are reasonable for resource management-use.

Burn Severity within Suitable Habitat where DFB Colonization is Probable

Data source: Rapid Assessment of Vegetation Condition following Wildfire (RAVG) and Soil Burn Severity (SBS) hybrid layer described in NRGG (2017) which assesses suitable Canada lynx habitat following 2017 wildfire incidents.

Criteria for attributing DFB Habitat estimations from R1 VMap products with RAVG+SBS-hybrid layer classes:

1) Polygons meeting suitable habitat with potential DFB colonization (as described previously; moderate and high susceptibility only) were selected for attribution

2) Selected polygons were attributed with RAVG+SBS-hybrid class and collapsed into a three-class burn severity rating for conditions immediately post-fire:

    a. Potential DFB habitat
        i. Unburned or minimal burn severity: RAVG+SBS Class 11
    b. Potential DFB habitat where DFB-attacks are Probable
        i. Low-moderate burn severity: RAVG+SBS Classes 12, 21, and 22
        ii. Moderate-high burn severity: RAVG+SBS Classes 13, 14, 23, 24
    c. No Potential or Probable DFB habitat
        i. Very high burn severity (direct fire-caused mortality): RAVG+SBS Classes 31-34

Note: estimation of locations where elevated probability of DFB-attack was based on Hood et al. (2007) modeling that indicated moderate fire-injury increases probability of DFB-attack.